UNITED STATES PATENT APPLICATION

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for

ADAPTIVE SIGNAL WEIGHTING SYSTEM

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PRIORITY INFORMATION

5   This application claims priority from provisional application Ser. No. 60/282,528 filed

April 9, 2001.

BACKGROUND OF THE INVENTION

This invention relates to signal conditioning systems, and in particular to a signal decoder

10   with adaptive signal weighting.

Various techniques for encoding and decoding a data signal (e.g., video or audio) are

known. For example, U.S. Patents 4,101,849 and 4,136,314 disclose an encoding technique that

compresses the data signal with high frequency preemphasis. The signal is then stored or

transmitted onto or across a medium, and the received data signal is expanded and deemphasized

15   in a complementary manner. Preemphasis involves altering the magnitude of select frequency

components of the signal with respect to the magnitude of frequency components, to reduce noise

and thus improve the signal-to-noise ratio (SNR). Similarly, deemphasis involves altering select

frequency components of a received encoded signal (e.g., a signal that was transmitted across a

communication channel or read from a storage medium), in either a negative or positive sense in a

20   complementary manner to the preemphasis applied to the signal.

U.S. Patents 4,101,849 and 4,136,314 disclose controlling the amount of preemphasis as a

function of the ratio of the energy in high and low frequency portions of the data signal. Of course

the amount of deemphasis is also controlled by the ratio of the energy in the high and low

frequency portions of the signal. However, a problem with this ratio technique is that it does not

efficiently use the bandwidth of the transmission channel or the storage medium.

U.S. Patent 4,539,526 discloses an adaptive signal weighting system for encoding and decoding a data signal. The technique disclosed therein preemphasizes only the high frequency signal components during encoding as a function of the spectral energy contained in the high frequency portion of the signal. On the decoder side the received signal is deemphasized in a complementary manner by providing a gain to the high frequency signal components based upon the spectral energy within the high frequency portion of the spectrum of the received signal. One problem with this technique is that it controls the amount of preemphasis/deemphasis based upon spectrum of only the high frequency components.

Therefore, there is a need for an improved technique for encoding and/or decoding a data signal that is transmitted across a data channel or stored and retrieved from a storage medium.

SUMMARY OF THE INVENTION

Briefly, according to an aspect of the present invention, a system for decoding an electrical input signal includes a filter that impresses a variable gain on the portion of input signal to deemphasize a spectral region of the input signal. The variable gain is set as a function of a variable gain control signal. A frequency detector generates the variable gain control signal in accordance with a frequency value wherein approximately one-half of the energy of the input signal is below the frequency value.

In one embodiment, the frequency detector includes a variable notch filter that receives and filters the input signal and provides a notch filtered signal value, wherein the notch filter includes a

notch set as a function of variable gain control signal. A mixer receives and mixes the notch

filtered signal value and a value indicative of the input signal, and provides a mixed signal

indicative thereof to an integrator, which integrates the mixed signal to provide the variable gain

control signal.

5   In a second embodiment, the frequency detector includes a low pass filter that filters the

input signal to provide a first filtered signal. A first absolute value detector receives the first

filtered signal and provides a first absolute filtered signal indicative thereof. An amplifier

amplifies the first absolute value signal to provide an amplified first absolute filtered signal. A

second absolute value detector receives the input signal and provides a second absolute filtered

10   signal. A comparator compares the amplified first absolute filtered signal and the second absolute

filtered signal that provides a control signal, which is indicative of the second control signal.

        These and other objects, features and advantages of the present invention will become more

apparent in light of the following detailed description of preferred embodiments thereof, as

illustrated in the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWING

        FIG. 1 is a block diagram illustration of a data communications system;

        FIG. 2 is a block diagram illustration of the expander of the system illustrated in FIG. 1;

        FIG. 3 is a block diagram illustration of the frequency detector of the expander;

20   FIG. 4 is an alternative embodiment frequency detector; and

        FIG. 5 is a block diagram illustration of the compressor of the system illustrated in FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a block diagram illustration of a data communications system 10. The system

includes a signal source 12 that provides a signal (e.g., audio and/or video) on a line 14 to a

5   compressor 16 (i.e., an encoder), which provides a compressed (i.e., companded) signal on a line

18 that is transmitted over a communications channel (i.e., a communication medium or a storage

media such as for example a tape, a CD, or an electronic memory device). The system also

includes an expander 20 that receives the encoded/compressed signal from the communications

medium or storage media, and decompresses the signal to provide a decompressed signal on a line

10   22. As known, transmitting a signal over a communications medium or writing a signal to a

storage media often results in the coupling of some undesirable noise to the compressed signal on

the line 18. The compressor 16 provides preemphasis to the high frequency portion of the input

signal on the line 14, and the expander 20 provides a complementary deemphasis to the high

frequency portion of its input signal.

15   FIG. 2 is a block diagram illustration of the expander 20. The expander 20 includes a first

bandpass filter (BPF) 32 that receives the compressed signal (e.g., a compressed audio signal) on

the line 18. The bandpass filter 32 preferably includes a passband in the frequency range of about

20 Hz - 20 kHz. The bandpass filter 32 provides a bandpass filtered signal on a line 34 to a

variable filter 36, a frequency detector 38 and a second bandpass filter 40. The variable filter 36

20   receives a control signal on a line 42 that controls the gain impressed on the high frequency

portion of the signal transmitted through the variable filter 36. The details of how this control

signal is generated shall be discussed in detail hereinafter.

The second bandpass filter 40 includes a passband (e.g., 50 Hz to 5 kHz) that provides a second bandpassed signal on a line 44 to a level detector 46. The level detector 46 generates a gain control signal on a line 47 to the gain control 37, that provides a decoder output signal.

5   According to an aspect of the present invention, the decoder 20 includes the frequency detector 38 that provides the control signal on the line 42. FIG. 3 is a block diagram illustration of the frequency detector 38. In this digital embodiment, the frequency detector 38 includes a notch filter 50 and a delay 52 that each receive the first bandpassed signal on the line 18. The notch filter 50 provides a notch filtered output signal on a line 54 to a mixer 56, which also

10   receives, on a line 58, a delayed version of the input signal. The mixer 56 mixes the signals on the lines 54, 58 and provides a mixed signal on a line 60. A multiplier 62 multiplies the mixed signal on the line 60 with a time constant value τ, and the resultant product is provided on a line 64. A summer 66 then sums the past value of a control value C_n with the signal value on the line 64. As a result, the control value C_n on the line 42 can be expressed as:

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$$C_n = C_{n-1} + (Q * \tau) \qquad\qquad\qquad \text{EQ. 1}$$

where Q is equal to the signal on the line 58.

The control value C_n is input to the notch filter 50 to control the location of the notch. For

20   example, as the value of the control value C_n increases, the frequency value of the notch

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increases. Similarly, as the control value C_n decreases, the frequency value of the notch also decreases. Of course, one of ordinary skill will recognize the system may be configured such that the opposite is true.

Referring still to FIG. 3, the transfer function for the notch filter 50 may be expressed as:

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$$1 + 2C_n z^{-1} + z^{-2} \qquad\qquad\qquad EQ.\ 2$$

The mean frequency detector 38 operates to drive the control value C_n to a value that causes the value of the signal on the line 60 to approach zero. For example, in steady state (i.e., the DC value of the signal on the line 60 is zero), the notch of the notch filter 50 is located at a frequency value such that approximately one-half of the energy of the signal on the line 18 is located less than the notch filter value, while the other half of the energy of the signal on the line 18 is located above the notch filter value.

Consider for example if the frequency spectrum of the input signal on the line 18 includes only frequency components of equal energy at 1 kHz and 3 kHz. In this case the mean frequency detector 38 would shift the notch of the notch filter 50 such that approximately one-half of the energy is above the notch while one-half the energy is below the notch (e.g., the notch is located at about 2 kHz). Once the mean frequency detector 38 reaches steady state in response to this input signal, the DC component of the signal on the line 60 will be zero and as a result the control signal value C_n will be relatively constant.

Referring again to FIG. 1, the compressor 16 and the expander 20 are similar to those disclosed in U.S. Patent 4,539,526, with the principal exception that the amount of preemphasis and deemphasis applied to the signal is determined by a novel frequency detection technique. Specifically, unlike the system disclosed in U.S. Patent 4,539,526, the expander of the present invention utilizes the entire signal spectrum to determine the amount of deemphasis to be applied by the variable filter 36. The decoder disclosed in U.S. Patent 4,529,526 looks at only the high frequency energy of the signal to determine the amount of deemphasis to be applied to the high frequency portion of the signal. In contrast, the expander/decoder of the present invention looks at entire signal spectrum to determine the frequency at which one-half of the input signal energy is below. A signal indicative of this frequency value is then used to determine the amount of deemphasis to be applied. Of course a complementary technique is used to compress the signal. In the interest of brevity elements that are substantially the same as those disclosed in U.S. Patent 4,529,526 shall not be discussed herein. For example, the first and second BPFs 32, 40, the variable filter 36, the level detector 46 and the gain control 37 are similar to the corresponding elements disclosed in U.S. Patent 4,529,526. Accordingly, U.S. Patent 4,529,526 is hereby incorporated by reference.

FIG. 4 is an alternative embodiment mean frequency detector 70. This embodiment includes a variable low pass filter 72 having an adjustable corner frequency. This filter 72 provides a low pass filtered signal on a line 74 to a gain function 76 having a value of two and the resultant amplified signal is provided to a first absolute value unit 76 that provides a first absolute value signal on a line 78. A second absolute value unit 80 receives the input signal on the line 18,

and provides a second absolute value signal on a line 82. A comparator 84 receives the first and second absolute value signals, and provides an output signal on a line 86 indicative of the difference between the signals. Specifically, if the value on the line 82 is greater than the value on the line 78, then the comparator 84 provides an output signal on the line 86 to increase the value of

5 the corner frequency of the low pass filter 72. The signal on the line 86 may be input to a low pass filter 88 to smooth the signal prior to providing it to the low pass filter 72 to set the corner frequency thereof. Similarly, if the value on the line 82 is less than the value on the line 78, then the comparator 84 provides an output signal on the line 86 to decrease the value of the corner frequency of the low pass filter 72. In general, the value of the signal on the line 86 is driven such

10 that the corner frequency of the low pass filter 76 is set to the one-half energy point of the signal on the line 18. That is, if the signal values on the lines 78 and 82 are equal, then the output value of the low pass filter 72 is one-half the value of the input signal on the line 18. As the input signal on the line 18 changes, the mean frequency detector 70 tracks the change to shift the corner frequency of the low pass filter 72 such that the value of the signals on the lines 78 and 82 are

15 equal.

FIG. 5 is a block diagram illustration of the compressor 16 of the system illustrated in FIG. 1. This compressor 16 is similar to the compressor disclosed in U.S. Patent 4,539,526, with the principal exception that the amount of preemphasis applied to the signal is determined by a novel mean frequency detector 102, which is complementary to the mean frequency detector 38 (FIG.

20 2). Specifically, unlike the system disclosed in U.S. Patent 4,539,526, the compressor of the present invention utilizes the entire signal spectrum to determine the amount of preemphasis.

Again, in the interest of brevity elements that are substantially the same as those disclosed in U.S. Patent 4,529,526 shall not be discussed at length herein.

Although the present invention has been shown and described with respect to several preferred embodiments thereof, various changes, omissions and additions to the form and detail

5   thereof, may be made therein, without departing from the spirit and scope of the invention.

What is claimed is: